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Effect of post-harvest treatments on physiological loss in weight and fungal spoilage of Langra mangoes (*Mangifera Indica* L.) during storage

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Abstract
The effect of calcium salts (calcium nitrate and calcium chloride) and Gibberellic acid on physiological loss in weight (PLW %), spoilage loss (%), economic life (days) and intensity of rotting of fruits during storage of Langra mangoes was studied. The fruits were treated with $Ca(NO_3)_2$ at the concentration of 1,2 and 3 per cent, $CaCl_2$ at the concentration of 1,2 and 3 per cent and GA_3 at the concentration of 50, 100 and 150 ppm. Untreated fruits served as the control. All treatments exhibited significant reduction in PLW and spoilage loss, increased economic life and delay in the onset of pathogenic invasion. At end of experiment, GA_3 100 ppm and $Ca(NO_3)_2$ at 2 per cent proved most promising treatment in these regards and were able to restrict the PLW at 17.86and18.33, Spoilage at 12.00 and 12.65 per cent respectively which was recorded 49.87 and 38.76 per cent respectively in case of control. The economic life under these treatments was 15 and 12 days in comparison to 6 days under control. These treatments were also proved excellent in restricting the invasion of pathogen up to 12th day of storage whereas fruits under control were found heavily infected on this day. The microorganism associated with the decay was identified as *Aspergillus niger*.

Keywords: Mango, Langra, Calcium nitrate, Calcium chloride, GA_3, PLW, Spoilage, Economic life, *Aspergillus niger*

Introduction
Mango (*Mangifera indica* L.), the king of fruits belongs to the family Anacardiaceae. Among the fruits of universal importance, mango is placed on top and is the most popular fruit among millions of people. Mango is fifth widely produced fruit crop of the world after bananas, apples, grapes and oranges. Mango is grown throughout the length and breadth of the country except the temperate and arid regions. The number one mango producing country in the world is India. It contributes approximately 50% of the global mango supply. In India, during 2015-16, it was grown in an area of 2.209 million hectares with a production of 18.643 million tonnes and productivity of 8.4 tonnes/hectare (Anonymous, 2017) [1].

Mango fruit has been found rich source of carbohydrate, minerals and vitamins having moisture 73.0 to 86.7 per cent, carbohydrate 11.6 to 24.3 per cent, protein 0.3 to 1.0 per cent (Kumar, 1999) [3, 10-13]. Among the cultivated varieties of Bihar, the variety Langra is most famous and is one of the most popular cultivars of India (Khara *et al*, 2016) [9]. In domestic market this variety has good demand and is able to fetch highest price in the market of Bihar. However, owing to its highly perishable nature and below average keeping quality, export potential of this variety is yet to be capitalised.

Mango showed highly prominent post-harvest loss because of its high perish ability and climacteric pattern of respiration. This massive reduction in weight of fruits during storage is also very common in mango. The possible cause of weight loss is assigned to moisture loss by process of evapo-transpiration and respiration. As estimated by Lashley (1984) [14], approximately 30 to 50% fruits go waste during post-harvest handling, storage and ripening. Singh *et al.* (1998) [19, 22-24] reported that in India, post-harvest loss of fresh mango fruits due to microbial decay varies from 20-33%.Therefore, a critical examination becomes imperative to prolong the shelf life of the fruits and to know the causes and remedies of post-harvest losses in fresh fruits in order to save the interest of farmer's community and consumers as well.

Among various causes of post-harvest losses, the diseases impart a heavy influence in tropics. The major spoilage is due to fungal infection that takes place after harvest and cause diseases during storage (Eckert, 1975) [6]. According to Kumar (1998) [3, 10-13] microorganisms like *Phoma* sp., *Diplodia natalensis*, *Penicillium* sp. and *Glomerella* sp. were found responsible for decay loss during the storage of Sipia cultivar of mango. Kumar (1999) [3, 10-13] reported that *Aspergillus* sp. *Botryodiplodia* sp. and *Diplodia* sp. were among those microorganisms, which were associated with the rotting of mango fruits during storage. Efficacy of pre and post-harvest applications of certain chemicals and growth hormones in minimising physiological loss in weight, spoilage loss and microbial infection during storage has been observed in past. The operationally feasible and more judicious post-harvest treatment of Gibberellic acid (GA_3) to extend shelf life of Amrapali mango was successfully investigated by Singh and Chundawat (1991) [23]. Mango fruits treated with calcium salts and GA_3 exhibited reduced rotting of fruits as reported by Kumar and Nagpal (1996) [11]. Patra and Sandhu (1992) [20] and Brahmachari *et al.* (1999) [3, 24] observed extended storage life of litchi fruits with slower rate of spoilage when subjected to post harvest dip in different concentrations of calcium salt for 5 minutes. GA_3 is known for lowering the rate of respiration and for its anti-senescent and antiseptic action (Kumar, 2005) [3, 10-13]. Mounika *et al*. (2017) [16] recorded the lowest PLW in Amrapali mango fruits treated with 2% $Ca(NO_3)_2$ as post-harvest application. As per the outcome of the experiments of Patel *et al*. (2018) [19] the application of GA_3 at both the concentrations (25 and 50 ppm) was beneficial to improve shelf life of mango fruits. The reduced percentage of spoilage was reported in aonla by Thokchom and Mandal (2018) [26] under the influence of post-harvest application of $CaCl_2$.Dalvadi*et al.* (2018) while working on jamun fruits reported that, GA_3 @ 100 ppm was able to significantly reduce the spoilage loss in stored fruits.

Keeping these facts in view, an investigation was carried out to find the effect of calcium salts and GA_3 on nature and extent of fungal spoilage in stored mangoes.

Materials and Methods

The experiment was conducted in the Department of Botany, Jai Prakash University Chapra (Bihar) during the cropping year of 2018-19. The physiologically matured fruits were purchased from the market and carried to the experimental laboratory in bamboo baskets. The maturity was judged on the basis of fruit colour changes from greenish to the pinkish, flatness of the tubercles and smoothness of the epicarp as suggested by Pandey and Sharma (1998) [17]. All the selected fruits were firm, uniform in size and maturity as well as free from any pests, diseases, injuries, blemishes and bruises. The fruits divided in different lots were dipped for five minutes in aqueous solution of different chemicals at different concentrations separately. The experiment consisted of 10 treatments which are $Ca(NO_3)_2$ at the concentration of 1,2 and 3 per cent, $CaCl_2$ at the concentration of 1,2 and 3 per cent and GA_3 at the concentration of 50, 100 and 150 ppm and Control. The control fruits were dipped in water and kept for comparison. Fruits were stored after air drying in bamboo baskets at room temperature. The storage was terminated on the day when the fruits exhibited 12 per cent or more loss due to rotting under best treatment. The data were recorded on physiological loss in weight (PLW) %, spoilage loss (%), economic life (days), intensity of rotting and microorganism associated with spoilage. The observations were recorded on 3 days interval. The cumulative physiological loss in weight of the fruits under storage was calculated on initial weight basis by subtracting final weight from the initial weight of the fruits and expressed in per cent. The spoiled fruits separated during storage were weighed separately the percentage of spoiled fruits was calculated against the original weight of fruits. The economic life of fruits under storage was determined by counting the number of days on the date on which cumulative spoilage percentage of the fruits in a particular treatment exceeded 12 per cent from the date of start of experiment. Number of days so obtained indicated the economic life of the fruits under that particular treatment. The intensity of rotting of mango fruits of under influence of different treatments was estimated on basis of affected surface area of the fruits and pathogens responsible for spoilage were identified. Fungal species were isolated from spoiled and infected fruits. Isolated fungal strains were identified using the conventional guidelines of fungus identification (Ellis, 1971; Samson and Varga, 2007) [7, 21]. Further these identified species were got confirmed from lab of ITCC (Indian Type Culture Collection Centre),Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi-110012 by referring the culture to this lab of international repute.

Results and Discussion

Physiological loss in weight (PLW %)

The physiological loss in weight (PLW) of fruits, in general, gradually increased under influence of all the treatments as the storage period advanced. It was with slower pace in the beginning but was at a faster pace as the storage period progressed (Table-1, Fig.-1). On the completion of storage period the minimum mean loss in weight (7.23%) was observed with $Ca(NO_3)_2$ at 2 per cent which was at par with $GA_3$100 ppm having 7.35 per cent PLW. Significantly maximum weight loss (19.47%) was found in control. Data based on the last day of observation revealed that minimum loss in weight (17.86%) of fruits was with GA_3 100 ppm which showed parity with $Ca(NO_3)_2$ at 2 per cent having 18.33 per cent PLW. Significantly maximum weight loss (49.87%) on that day was noted under control. These findings substantiate the earlier reports on this aspect in mango (Mounika *et al*., 2017) [16]; litchi (Brahmachari *et al.,* 1999) [3, 24] and guava. The PLW indicates the progress of ripening in climacteric fruits, higher the PLW more the ripening (Ingle *et al*., 1981) [8]. Calcium is essential for structural integrity of both cell wall and plasma membrane. Bantash and Arasimovich (1989) [2] concluded that exogenous incorporation of calcium retarded hydrolysis of protopectin of fruits during post-harvest ripening, inhibited fruit softening and extended storability of apples. The possible reason of reduction in weight loss with GA may be due to some chemical changes caused by it within the fruit so that it could retain more water against the force of evaporation and possibly they may also alter some of the proteinous constituents of the cell wall so as to increase affinity for water (Mitchell, 1949) [15].

Table 1: Physiological loss in weight (%) of mango fruits during storage under different post-harvest treatments

Treatments	Days in storage						Mean
	0	3	6	9	12	15	
T_1- $Ca(NO_3)_2$ at 1%	0.00	2.87	6.68	10.48	17.02	26.47	10.59
T_2- $Ca(NO_3)_2$ at 2%	0.00	2.05	4.76	7.88	10.35	18.33	7.23
T_3- $Ca(NO_3)_2$ at 3%	0.00	2.36	5.16	8.31	11.89	22.85	8.43
T_4- $CaCl_2$ at 1 %	0.00	3.01	7.25	12.66	17.53	29.95	11.73
T_5- $CaCl_2$ at 2%	0.00	2.71	5.60	9.66	13.55	24.42	9.32
T_6- $CaCl_2$ at 3%	0.00	2.78	6.85	9.43	13.98	27.53	10.10
T_7- GA_3 at 50 ppm	0.00	2.83	5.00	11.34	17.75	22.65	9.93
T_8- GA_3 at 100 ppm	0.00	2.25	4.99	8.10	10.88	17.86	7.35
T_9- GA_3 at 150 ppm	0.00	2.63	5.52	9.97	12.95	23.00	9.01
T_{10}- Control (Water)	0.00	6.79	10.72	18.62	30.79	49.87	19.47
Mean	0.00	3.03	6.25	10.65	15.67	26.29	
SEm±		0.12	0.15	0.15	0.26	0.19	
CD at %		0.25	0.28	0.27	0.55	0.51	

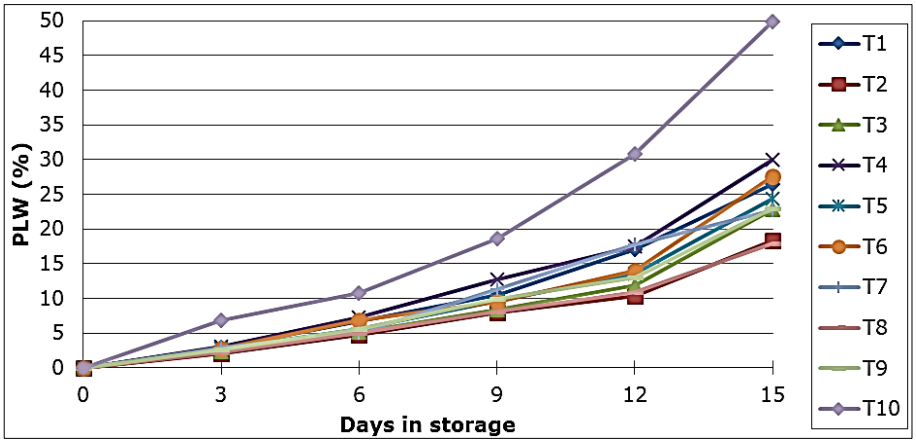

Fig 1: PLW (%) of mango fruits during storage

Spoilage loss (%)

Spoilage of fruits increased as the storage period advances. At the end of experiment GA_3 100 ppm and $Ca(NO_3)_2$ at 2 per cent were most effective in minimising spoilage loss which were at par to each other.. Significantly maximum loss (38.76%) was obtained under control. On careful examination of data it was observed that GA_3 100 ppm was able to exhibit minimum spoilage loss on all the days of observations which was closely followed by $Ca(NO_3)_2$ at 2 per cent (Table-2, Fig.-2). Similar trend of spoilage of mango during storage was also observed by Singh and Narayana (1999) [22] and Mounika *et al.* (2017) [16]. The least spoilage with GA_3 might be due to its anti-senescent and antiseptic action which inhibited germination of spores and checked the growth of pathogens (Kumar, 1999) [3, 10-13]. Significant reduction in fruit rot with the application of calcium salts might be due to its effect on retaining the firmness of tissue and inhibiting softness and senescence of fruits. Calcium retards fruit softening and imparts resistance against pathogens causing decay (Conway, 1985) [4].

Table 2: Spoilage loss (%) and economic life of mango fruits during storage under different post-harvest treatments

Treatments	Days in storage						Mean	Economic life (Days)
	0	3	6	9	12	15		
T_1- $Ca(NO_3)_2$ at 1%	0.00	0.00	1.00	7.55	17.36	29.99	9.32	9
T_2- $Ca(NO_3)_2$ at 2%	0.00	0.00	0.00	3.05	9.05	12.65	4.13	12
T_3- $Ca(NO_3)_2$ at 3%	0.00	0.00	0.00	3.15	10.48	16.37	5.00	12
T_4- $CaCl_2$ at 1 %	0.00	0.00	1.25	9.00	19.94	30.85	10.17	9
T_5- $CaCl_2$ at 2%	0.00	0.00	0.00	7.83	13.23	21.10	7.03	9
T_6- $CaCl_2$ at 3%	0.00	0.00	0.00	6.21	15.85	26.97	8.17	9
T_7- GA_3 at 50 ppm	0.00	0.00	0.00	6.00	14.02	23.60	7.27	9
T_8- GA_3 at 100 ppm	0.00	0.00	0.00	2.95	8.92	12.00	3.98	15
T_9- GA_3 at 150 ppm	0.00	0.00	0.00	3.20	10.85	16.75	5.13	12
T_{10}- Control (Water)	0.00	0.00	4.85	12.21	21.15	38.76	12.83	6
Mean	0.00	0.00	0.71	6.12	14.09	22.90		
SEm±	0.00	0.00	0.02	0.05	0.06	0.21	0.06	
CD at %	0.00	0.00	0.01	0.11	0.15	0.67	0.18	

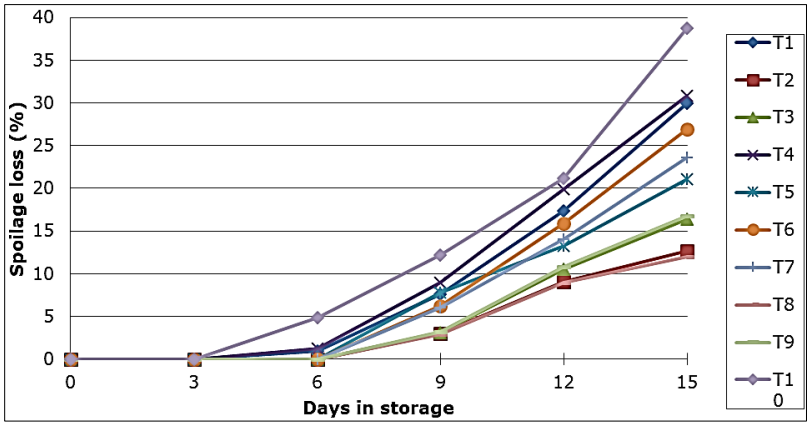

Fig 2: Spoilage loss (%) of mango fruits during storage

Economic life of fruits

When the economic life of fruits was considered on the basis of spoilage loss within 12 per cent, the maximum storage life i.e. 15 days was exhibited by the treatment GA_3 100 ppm. $Ca(NO_3)_2$ at 2%, $Ca(NO_3)_2$ at 3% and GA_3at 150 ppm exhibited the economic life of 12 days. The fruits under control were able to be stored successfully up to 6 days only (Table-2, Fig.-3). Similar increase in economic life of fruits with application of calcium salts and GA_3 was reported earlier by Kumar (2005) [3, 10-13] and Mounika *et al.* (2017) [16].

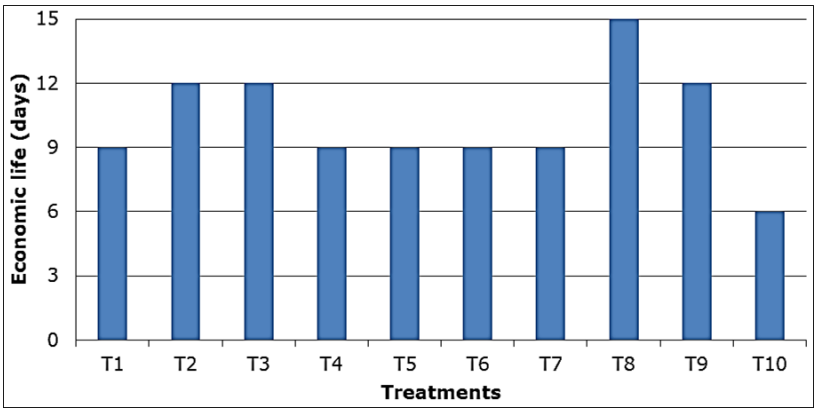

Fig 3: Economic life (days) of mango fruits during storage

Intensity of rotting and microorganism associated (Identification of fungal species)

The rotting of the fruits started from the 6th day of storage with light intensity in fruits of control. On 12th day, all the treatments except $Ca(NO_3)_2$ at 2 per cent and GA_3 at 100 ppm, showed the light to moderate intensity and control having the heavy intensity of rotting. Finally on 15th day of storage $Ca(NO_3)_2$ at 2 per cent and GA_3 at 100 ppm were able to restrict the rotting to the light intensity. Rest others having moderate to heavy intensity of rotting on this day of storage.So far as pathogens responsible for rotting were concerned, the affected parts of mango fruits were used to isolate the pathogens and cultured in the laboratory on PDA medium. All the pathogens isolated from the fruits under the all treatments identified as *Aspergillus niger* (Table-3). Association of *Aspergillus niger* with the spoilage of mango was also established earlier by Pandey *et al.* (1982) and Kumar (1999) [3, 10-13]. Increase in the intensity of rotting with the advancement of storage period was due to the multiplication of invaded pathogens. Kumar and Nagpal (1996) [3, 10-13], opined that the reduction in fruit rot with GA_3 could possibly be due to the fact that it might have reduced or changed the biochemical changes in fruits. This in turn imparted some resistance against the penetration or growth of pathogen in the fruits. Reduction in rotting under influence of $Ca(NO_3)_2$, as per Conway (1985) [4], was might be due to association of calcium in imparting a degree of resistance to decay by pathogens.

Table 3: Intensity of rotting and microorganism associated during storage of mango fruits under influence of different post-harvest treatments

Treatments	Days in storage					Microorganism associated
	0-3	6	9	12	15	
T_1- $Ca(NO_3)_2$ at 1%	0	0	+	+ +	+ + +	*Aspergillusniger*
T_2- $Ca(NO_3)_2$ at 2%	0	0	0	0	+	*Aspergillusniger*
T_3- $Ca(NO_3)_2$ at 3%	0	0	0	+	+ +	*Aspergillusniger*
T_4- $CaCl_2$ at 1%	0	0	+	+ +	+ + +	*Aspergillusniger*
T_5- $CaCl_2$ at 2%	0	0	0	+	+ +	*Aspergillusniger*
T_6- $CaCl_2$ at 3%	0	0	0	+	+ +	*Aspergillusniger*
T_7- GA_3 at 50 ppm	0	0	+	+ +	+ + +	*Aspergillusniger*
T_8- GA_3 at 100 ppm	0	0	0	0	+	*Aspergillusniger*
T_9- GA_3 at 150 ppm	0	0	0	+	+ + +	*Aspergillusniger*
T_{10}- Control (Water)	0	+	+ +	+ + +	+ + +	*Aspergillusniger*

Intensity of rotting (On the basis of surface area): 1 to 5% area = Light (+), 5 to 10% area = Moderate (+ +) more than 10 % area = Heavy (+ + +)

Conclusion

Mango fruits treated with $Ca(NO_3)_2$ at 2 per cent and GA_3 at 100 ppm, recorded significantly lower physiological loss in weight(%), reduced spoilage loss. They were found effective in increasing the economic life of fruits up to 15 days after harvest and delaying the onset of fungal invasion during storage. Hence it can easily be opined that calcium nitrate at 2 per cent and GA_3 at 100 ppm as post-harvest application can be used during storage of mango fruits in order to extend the shelf life with reduced post-harvest losses.

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